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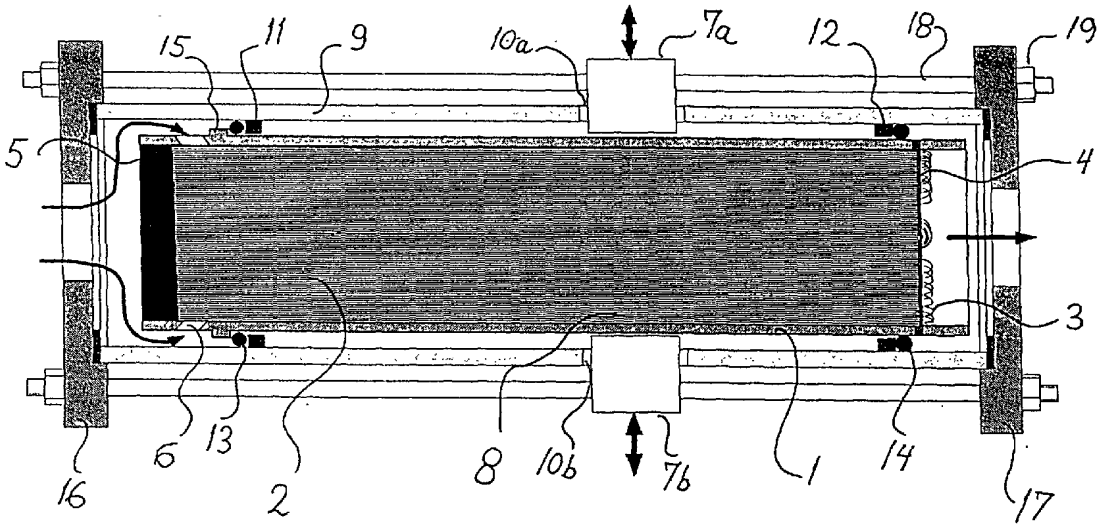
(54) **Title:** A DEVICE AND A METHOD FOR FILTERING A FLUID



(57) **Abstract:** A device for filtering a fluid is provided, wherein said filtering device comprises a fibre housing (1) having an inlet end (5) with at least one inlet and an outlet end (3) with at least one outlet. The fibre housing surrounds and defines an outer bound for a plurality of fibres (2) extending longitudinally in the fibre housing between the inlet end and the outlet end, whereby longitudinally extending interspaces is provided between the fibres, with said interspaces defining a plurality of flow passages for the fluid. At least part of the fibre housing is formed of a flexible membrane surrounding the fibres, and compressing means (7a,7b) is provided for creating a pressure on an outer surface of the flexible membrane thereby compressing the fibres in a radial direction at least one location along the length of the fibres.

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

A DEVICE AND A METHOD FOR FILTERING A FLUID

BACKGROUND OF THE INVENTION

The present invention relates to a device and a method for filtering a fluid. More particularly the present invention concerns a device for filtering a fluid wherein a plurality of fibres extend longitudinally in the direction of the fluid flow during filtration of said fluid.

PRIOR ART

US patent No. 4,219,420 discloses an arrangement for filtering a contaminated fluid or medium. According to the disclosure of this patent a plurality of fibre bundles are located on a support and extend within a filter housing in direction between an inlet and an outlet of the housing. The fluid to be filtered is introduced through the inlet in a direction towards the outlet. The contaminated particles become arrested among the fibres as it passes through the plurality of fibre bundles. In order to improve the "depth effect" of the fibre bundles, the fibres may have different lengths. Here the quality of the filtered fluid depends on the density of the fibre bundles. However, in order to increase the quality of the filtration process, the density of the fibres must be increased, which requires more fibre bundles to be inserted into the filter housing.

An improvement to the filter of US patent No. 4,219,420 has been proposed in EP 0 280 052. Here a filter housing comprises a supporting means with a plurality of fibre bundles attached to the supporting means and extending within the filter housing in direction between an inlet and an outlet. A flexible water-proof membrane is provided within the filter housing to constitute a pressure chamber. When pressurised during the filtration process, the membrane press the plurality of fibre bundles to form a frustrum-like filter chamber, and the fluid becomes filtered as it passes through the frustrum-like chamber. Here the density of the fibres and thus the quality of the filtration can be controlled by adjusting the pressure in the pressure chamber whereby the compressing of the fibres is adjusted.

Another filter having fibres extending longitudinally in the direction of the fluid flow, and wherein the density of the fibres is adjusted by compressing the fibres, is disclosed in WO 94/11088. Here the fibres are arranged within an opening defined by a retaining member, and a displacement member comprising a conical-shaped part is arranged in the centre of the fibres. By moving the displacement member in a direction along the fibres, the compressing of the fibres against the retaining member is adjusted whereby the density of the fibres and the quality of the filtration is controlled.

Thus, the principles of having a fluid filtration wherein a plurality of fibres extend longitudinally in the direction of the fluid flow, and wherein the quality of the filtration is controlled by adjusting the compression and thereby the density of the fibres are known.

The filtering device of US patent No. 4,219,420 uses a pressure chamber in order to compress the fibres, whereas the filtering device of WO 94/11088 has a conical-shaped displacement member arranged in the centre of the fibres in order to compress the fibres against a retaining member. Both of these filtering devices are relatively expensive to produce.

However, today there is much focus on the quality of water for use domestically as well for industrial purposes, partly due to the increasing pollution of the environment and partly due to increasing public awareness with regard to the quality of food and beverages. Furthermore, the population growth results in an even higher demand for a simple, inexpensive and effective device for filtering a fluid such as water.

Thus, there is an increasing need for a simple, inexpensive and effective device for filtering a fluid. Therefore, it is an object of the present invention to provide a device for filtering a fluid, which device is effective in filtering the fluid, is inexpensive to produce and is simple to operate.

SUMMARY OF THE INVENTION

In order to provide such an improved filtering device, the present invention in a first aspect provides a device for filtering a fluid, said device comprising:

a fibre housing having an inlet end with at least one inlet and an outlet end with at least one outlet, said fibre housing surrounding and defining an outer bound for a plurality or a bundle of fibres extending longitudinally in the fibre housing between the inlet end and the outlet end, whereby longitudinally extending interspaces is provided between the fibres, said interspaces defining a plurality of flow passages for the fluid. Here, at least part of said fibre housing is formed of a flexible membrane surrounding the fibres, and compressing means is provided for creating a pressure on an outer surface of the flexible membrane thereby compressing the fibres in a radial direction at at least one location along the length of the fibres. It is preferred that the plurality of fibres is extending in substantially the whole length of the fibre housing from the inlet end to the outlet end.

The fibre housing may have the form of a tube-like member, but it should be understood that the fibre housing may have any convenient form. Thus, at least part of the fibre housing may have a cross sectional geometric shape which is substantially equal to a shape selected from the group comprising: a circle, an oval, an ellipse, the shape of a drop, and a polygon. Here, said polygon shape may be selected from the group comprising: a triangle, a rectangle, a pentagon, a hexagon, a heptagon, and an octagon.

According to a preferred embodiment of the invention, the compressing means may be adapted to create a pressure on a part or a portion of the outer surface of the flexible membrane, where said part or portion has a dimension or dimensions in the longitudinally direction of the fibres being smaller than the total length of the fibres within said fibre housing. Here, the dimension of said pressure part or portion in the longitudinally direction of the fibres may preferably be below 0,8 times the total length of the fibres within said fibre housing, such as below 0,6 times, such as below 0,5 time, such as below 0,4 times, such as below 0,2 times, or such as below 0,1 times.

It is also within a preferred embodiment to have the compressing means being adapted to create a pressure on a part or a portion of said outer surface of the flexible membrane, where said part or portion is at least partly covering an outer circumference of said membrane. Here, the pressure part or portion may be only partly

covering an outer circumference of said membrane. Thus, the pressure part or portion may be covering below 90% of an outer circumference of said membrane, such as below 80%, such as below 70%, such as below 60%, such as below 50%, such as below 40%, such as below 30%, or such as below 20%.

It should be understood that by only providing a pressure on a part of the outer surface of the flexible membrane, the interspaces of the uncompressed parts of the fibres will be larger than the interspaces of the compressed part of the fibres. Here, the filtered particles will be left in the interspaces of the uncompressed part of the fibres in the inlet end, and the filtering efficiency may to a great extent be controlled by the dimensions of the part of the flexible membrane on which a pressure is provided.

It is preferred that the location at which the fibres are compressed is a predetermined location. Here it should be noted that the distance from the inlet end of the fibre housing to said location of compression, and also the distance from the outlet end of the fibre housing to said location of compression will also have an influence on the filtering performance. Different arrangements of said location of compressing may be used, but the distance from the inlet end of the fibre housing to said location may be at least 25% of the total length of the fibre housing, such as at least 33%, such as at least 40%, such as at least 50%, such as at least 55%, such as at least 60%. In a preferred embodiment the centre of the location of compressing is arranged with a distance from the inlet end of about 2/3 of the total length of the fibre housing, leaving a distance of about 1/3 of the total length of the fibre housing to the outlet end.

It should be understood that different lengths of the distance from the inlet end to the outlet end of fibre housing may be used. However, it will be most convenient to us a length defined by the length of commercially available fibres or bundle of fibres. Thus, the distance between the at least one inlet and the at least one outlet may be between 10 cm and 200 cm, such as between 30 cm and 150 cm, such as between 40 and 80 cm. If a bundle of fibres having a length of about 60 cm is used, a preferred distance between the at least one inlet and the at least one outlet may be between 50 and 70 cm, or about 60 cm.

The distance between the at least one inlet and the location of compression may be selected accordingly. Thus, the distance between the at least one inlet and said location may be between 5 cm and 100 cm, such as between 10 cm and 90 cm, such as between 20 and 80 cm, such as between 30 and 50 cm, such as around 40 cm.

The distance between the at least one inlet and the at least one outlet may in accordance with another embodiment be between 10 cm and 60 cm, such as between 20 cm and 40 cm, such as between 25 and 35 cm. Here, a plurality or a bundle of fibres having a length around 30 cm may be used.

Again the distance between the at least one inlet and the location of compression may be selected accordingly to be between 5 cm and 80 cm, such as between 10 cm and 60 cm, such as between 15 and 30 cm, such as around 20 cm.

The compressing means may create the pressure on the outer surface of the flexible membrane in different ways. In a preferred embodiment of the invention, the compressing means is a pressure chamber, wherein an inner wall of said pressure chamber may be formed of at lest part of the flexible membrane of the fibre housing. The pressure chamber may have one or more inlet/outlets providing a pressurizing aperture and a release aperture. In another preferred embodiment of the invention the pressure is created through one or more substantially solid compressing member(s) being in contact with said outer surface. The compressing member(s) may have non-flexible and/or flexible part(s), but it is preferred that the compressing member(s) may be at least partly flexible or yielding. It should however be noted that by using such substantially solid compressing member(s) a much more simple construction may be achieved than when creating the pressure on the membrane by use of a gas, a liquid or a fluid. The means for compressing may preferably be adapted to vary or control the pressure created thereby, so as to thereby vary or control the total cross-section area of the flow passages at said location and so as to vary the minimum size of particles being filtered through the fibres.

The compressing means may comprise a clamp. The compressing means may further or alternatively comprise at least two blocks being positioned on opposite sides of the flexible membrane, so as to compress the fibres from two sides.

It is preferred that the compressing means comprises hydraulic means for creating and/or controlling the pressure. Preferably, the compressing means is adapted to compress the plurality of fibres in a radial direction with a pressure of between 1-20 bar, such as between 3-15 bar, such as between 5-10 bar.

The fibre housing may be made of different materials with different flexibility. However, it is preferred that the fibre housing is made of the same material in all its length, whereby the fibre housing is formed of a flexible membrane in substantially all its length. The fibre housing may be made of any suitable material, but it is preferred that the material is watertight and it is further preferred that the material is selected from a group comprising: PE (polyethylene), softened PVC (polyvinyl chloride), nylon, Teflon, and rubber. Here, the rubber material may be EPDM-rubber.

According to an embodiment of the present invention, the fibre housing is arranged within a holding member. Here, the holding member may be made of a substantially solid material, such as for example stainless steel. The holding member may preferably have one or more openings in order to allow the compressing means to create a pressure on the outer surface of said flexible membrane of the fibre housing. Thus, the holding member may have two openings for allowing the compressing means to create a pressure on the outer surface of said flexible membrane. The holding member may preferably be formed as a tube-like member.

The holding member may be formed to have a fluid inlet being sealingly connected to the inlet end of the fibre housing, and a fluid outlet end being sealingly connected to the outlet end of the fibre housing.

In order to maintain a desired filtering operation of the device of the present invention, a longitudinal tension may be applied to the fibres when arranged in the fibre housing. Thus, the filtering device may comprise means for maintaining a longitudinal tension in the fibres. Such means may be provided by the fastening of the fibres within the fibre housing and the arrangement of the fibre housing within the holding member.

Any suitable inner diameter of the fibre housing may be selected. However, it will be most convenient to select a diameter which will fit to the diameter of commercially

available bundle of fibres. Preferably, the inner diameter of the fibre housing may be between 1 cm and 20 cm, such as between 2 cm and 15 cm, such as between 3 cm and 10 cm, such as between 4 cm and 8 cm, such as around 5 cm.

Different types of fibres may be used for the filtering device, where the type of fibres may be selected in order to fulfil the requirements of a given filtration process. Thus, the fibres may be porous or non-porous, the fibres may be solid or hollow, and the fibres may comprise transparent fibres. In a preferred embodiment the fibres comprise polyester fibres or nylon fibres. It is also preferred that the fibres have a substantially circular cross-section. Here the cross-sectional dimension may vary according to the particles to be filtered from the fluid, but it is preferred that the diameter is of at most 5 mm, such as at most 2 mm, such as in the range of 0.001-1 mm, such as in the range of 0.01-0.5 mm.

When using hollow fibres, the fibres may preferably be closed at the fibre ends. Here, at least part of the fibre ends may be arranged in the same end of the fibre housing as an inlet to the fibre housing.

When arranging the fibres in the fibre housing it is preferred that the fibres at the inlet end of the fibre housing are attached to an end part of the fibre housing. Here, the fibres at the inlet end of the fibre housing may be glued to the end part or glued to a holding member, which is arranged at the end part. The fibres may be glued by means of epoxy. In a preferred embodiment, the fibres have free fibre ends at the opposite end of the inlet end of the fibre housing. However, the present invention also covers an embodiment in which the fibres, in their respective ends, are attached to an end part of the fibre housing. Also here, the fibres may be glued to the end parts or to holding members arranged at the end parts by means of epoxy.

According to an embodiment of the present invention the plurality of fibres within the fibre housing may comprise a bundle of fibres being bent so that a resulting length of the bent bundle of fibres is approximately between 1/3 and 2/3 of the length of the non-bent fibres, preferably around half the length of the non-bent bundle of fibres. Here, the bent end part of the bent bundle of fibres may be arranged in the outlet end of the fibre housing. However, the invention also covers embodiments where

the bent end part of the bent bundle of fibres are arranged in the inlet end of the fibre housing.

When the bent end part of the bent bundle of fibres is arranged in the outlet end of the fibre housing, the fibres may be arranged and bent around a cross-shaped element arranged at the outlet end of the fibre housing. However, in a preferred embodiment the two members of the cross are arranged at a distance to each other, whereby about half of the bent fibres will be arranged at a first distance to the outlet end and the remaining fibres will be arranged at a second distance to the outlet end.

Although it may be preferred to have a single location of compression of the fibres, it is also within the scope of the present invention to have the compressing means adapted for compressing the fibres at several locations along the length of the fibres. Hereby the capacity of accumulation of filtered particles may be changed or controlled along the length of the fibre housing.

The filtering device of the first aspect of the present invention may be used for filtration when arranged in a filtration system. Thus, according to a second aspect of the present invention there is provided a system for filtering a fluid, said system comprising: a filtering device according to any of the embodiments of the first aspect of the invention, means for passing a fluid to be filtered through the flow passages of the compressed fibres, and means for maintaining the fibres in a compressed condition while passing the fluid through the flow passages.

This system may further comprise means for releasing the pressure on the outer surface of the flexible membrane thereby leaving the fibres in an uncompressed condition, and means for passing a liquid and/or a gas through the uncompressed fibres in a direction from the inlet towards the outlet or in an opposite direction, so as to forward flush or backward flush the device.

Here, the liquid to be passed through the uncompressed fibres so as to flush the fibres may be unfiltered fluid, but it may also be another liquid such as tap water. If a gas is used for the flushing, the gas may be compressed air.

In a preferred embodiment of the filtering system, the means for compressing the fibres, the means for releasing the pressure, the means for passing fluid through the compressed fibres, and the means for passing a liquid or a gas through the uncompressed fibres so as to flush the device are computer controlled.

It is also within the scope of the present invention to provide a method of filtering a fluid. Thus, according to a third aspect of the present invention, there is provided a method for filtering fluids through a device or a system according to any of the embodiments of the first and the second aspects of the present invention, said method comprising: passing the fluid through said device,
compressing the fibres in a radial direction at a location along the flexible membrane, so as to reduce the total cross-sectional area of the fibres and thereby the cross-sectional area of the flow-passages, whereby the cross-sectional areas of the flow-passages gradually decrease towards said location, and
maintaining the pressure on the fibres while passing the fluid through the flow-passages.

The above method may also further comprise the step of transmitting ultraviolet light across the fibres, so as to kill bacteria and/or virus in said filtered particles by use of ultraviolet light.

It is further within the scope of the present invention to provide a method of flushing a filtering device. Thus, according to a fourth aspect of the invention, there is provided a method of flushing a device or a system according to any of the embodiments of the first and second aspects of the present invention, said method comprising the steps of; releasing the pressure on the fibres, and passing liquid or gas through the uncompressed fibres. Here, the liquid or gas may pass the uncompressed fibres in a direction from the inlet towards the outlet or in an opposite direction, so as to forward flush or backward flush the device.

Other objects, features and advantages of the present invention will be more readily apparent from the detailed description of the preferred embodiments set forth below, taken in conjunction with the accompanying drawings.

BRIEF DESRIPTION OF THE DRAWINGS

Fig. 1 is a longitudinal section view of a first embodiment of a filtering device according to the present invention,

Fig. 2 is a block diagram showing a filtering system using a filtering device according to the present invention,

Fig. 3 is a longitudinal section view of a second embodiment of a filtering device according to the present invention, and

Fig. 4 is a block diagram showing a second embodiment of a system using a filtering device according to the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

In Fig. 1 is shown a longitudinal section view of an embodiment of a filtering device according to the present invention. The filtering device of Fig. 1 comprises a fibre housing 1 having the form of a tube. Here, the fibre housing 1 is made of a flexible, watertight material in all the housing length, whereby the fibre housing is formed as a flexible membrane surrounding a bundle of fibres 2. The bundle of fibres 2 comprises a plurality of fibres extending longitudinally in the fibre housing 1.

In the illustrated embodiment the fibres are bent to thereby obtain a bundle of bent or folded fibres 2 having a length being about half the length of the non-bent fibres. The bent end of the fibres is arranged in an outlet end 3 of the fibre housing 1. Here the fibres may be bent around a cross 4 secured to the fibre housing 1 by gluing by means of epoxy. The free ends of the fibres are arranged in an inlet end 5 of the fibre housing 1. Here, it is preferred that the fibres are glued to the inlet end 5 by means of epoxy resulting in a watertight end surface at the inlet end 5. The bundle of fibres 2 should be substantially equally spaced when arranged in the epoxy of the inlet end 5 in order to obtain a number of substantially equally sized interspaces defining flow passages. A number of inlets 6 are arranged in the side-wall of the fibre housing 1 near the inlet end 5, whereby a fluid can be conducted into the fibre housing 1. The fibre housing 1 is open at the outlet end 3, whereby the fluid can be discharged from the fibre housing 1.

In the illustrated embodiment of Fig. 1, the fibre housing 1 is made of a flexible material such as softened PVC or PVC-flexible, and the side-wall of the fibre housing has a thickness of about 5 mm and the inner diameter of the fibre housing is about 50 mm, giving an outer diameter about 60 mm. The cross 4 is made of stainless steel and has a diameter of 2 mm. The fibres may for example be hollow fibres of Tynex® nylon (available from the DuPont Company) with an unfolded length of 600 mm and a diameter in about 0.15 mm. However, solid fibres may also be used. Thus, the bent or folded length of the fibres in the bundle 2 will be about or a little less than 300 mm. The length of the fibre housing will then be about or a little more than 300 mm. It should be noted that the fibre housing 1 may also be made of a rubber material such as EPDM-rubber,

When the fibres are in an uncompressed condition the interspaces between the fibres are defined by the arrangement of the fibres at the inlet end 5 and the arrangement of the fibres around the cross 4 at the outlet end 3. Due to the arrangement around the cross 4, the size of the interspaces and thereby the flow passages may vary slightly from the inlet end 5 to the outlet end 3. It is also within an embodiment of the present invention to have the two members of the cross 4 separated from each other with a distance around 20 mm.

It is to be understood that the minimum size of particles to be filtered from a fluid is a function of the diameter of the fibres and the packing or cross-sectional density of the fibres. Thus, the filtered particle size decreases with a decreasing fibre diameter. Although it is preferred to have a relatively high density of fibres it is important that the cross-sectional area of the flow passages is larger at a distance from the location of the compressed fibres than at said location in order to avoid clogging.

When using the filtering device of Fig. 1 for fluid filtration the flexible membrane surrounding the fibre bundle 2 may be compressed at a radial direction at a location along the housing 1. Hereby the total cross-sectional area of the interspaces between the fibres and thereby the cross-sectional area of the flow passages is reduced at said location with the cross-sectional areas of the flow-passages being gradually decreased towards this location. Thus, the cross-sectional area of the flow

passages and thereby the filtering effect may be varied by varying the external pressure on the flexible membrane.

In order to compress the fibres of the fibre bundle 2, the filtering device of Fig. 1 comprises compressing means in the form of a clamp having two curved jaws 7a, 7b. Here the jaws 7a, 7b are made of stainless steel having a coating of softened PVC on the surfaces for contacting the flexible membrane of the fibre housing 1. When the jaws 7a, 7b are pressed against the fibre housing 1, the fibres are compressed and the filtering device can be used for filtration of the fluid. When the fluid is conducted through the fibre housing the filtered particles will be deposited in the inlet side of the fibre housing 1 between the inlets 6 and the location 8 of the compressed fibres.

In order to obtain sufficient space for the deposited particles and in order to avoid an early clogging of the filtering device, the jaws 7a, 7b and thereby the location of compressing 8 is preferably arranged so that about 2/3 of the length of the fibre housing is on the inlet side of the jaws 7a, 7b and about 1/3 of the length of the fibre housing is on the outlet side of the jaws 7a, 7b. For the filtering device of Fig. 1 the width of the jaws 7a, 7b is about 25 mm. The contacting surfaces of the jaws 7a, 7b are formed so that each surface covers about 1/3 of the outer diameter or circumference of the uncompressed fibre housing 1.

The jaws or blocks 7a, 7b of the compressing means may be controlled manually or by hydraulic means. When using hydraulic means the pressure of the compressing means may be controlled electronically by use of for example a computer. For the filtering device of Fig. 1 filtration processes have been carried out with a pressure around two tons on the compressing means 7a, 7b, whereby the fibre bundle 2 is compressed.

In order to support or hold the fibre housing 1 of Fig. 1 a holding member 9 is provided. The holding member has the form of a tube with a fluid inlet end and a fluid outlet end and with two oppositely arranged openings 10a, 10b allowing the compressing means 7a, 7b to compress the flexible membrane of the fibre housing 2. The holding member or pipe 9 has a first inner collar 11 at the inlet end and a second inner collar 12 at the outlet end, with a first o-sealing ring 13 being arranged

around the fibre housing 1 at the inlet end 5 and being in sealingly engagement with the first inner collar 11, and with a second o-sealing ring 14 being arranged around the fibre housing 1 at the outlet end 3 and being in sealingly engagement with the second inner collar 12. In the embodiment shown in Fig. 1 there is also formed an outer collar 15 at the inlet end 5 of the fibre housing 1, whereby the first o-sealing ring 13 is placed between the outer collar 15 and the first inner collar 11. The holding member or pipe 9 further has an inlet flange 16 arranged at the fluid inlet end and an outlet flange 17 arranged at the fluid outlet end. The flanges 16,17 are secured to the holding member 9 with bolts 18 and corresponding nuts 19.

The inlet flange 16 is dimensioned to fit a fluid inlet pipe, and the outlet flange 17 is dimensioned to fit a fluid outlet pipe.

For the filtering device of Fig. 1, the inlet and outlet pipes are ¾ inches pipes, and the holding member or pipe 9 is made of stainless steel with an outer diameter of 100 mm and a length around 360 mm.

When using softened PVC for the fibre housing 1, the stiffness of the housing 1 will be large enough to ensure a sealingly engagement between the inner collar 12 and the o-sealing ring 14. This sealingly engagement is further amplified by the pressure of the fluid inside the fibre housing 1. However, if a rubber membrane is used for the fibre housing 1 it may be necessary to reinforce the outlet end 3 of the fibre housing 1.

It should be understood that a major advantage of a filtering device according to the present invention is the possibility of flushing the fibres when the pressure on the fibres is released. The flushing process may be either a forward flushing or a backward flushing process. This is illustrated in Fig. 2 which is a block diagram showing a filtering system using a filtering device according to the present invention. The filtering device may preferably be the device shown in Fig.1, but any other filtering device according to the present invention may be used.

The system of Fig. 2 comprises a filtering device 41 according to the present invention. The filtering device 41 has a fibre housing 42 within a holding member 43 having openings 44a, 44b for compressing means 45a, 45b, which compressing means

can create a pressure on a flexible membrane of the fibre housing 42. The filtering device 42 further has a fluid inlet end 46 and a fluid outlet end 47 for connecting to fluid inlet and outlet pipes 48, 49, respectively.

The system of Fig. 2 further comprises a container for unfiltered fluid 50, with a pipe 51, which via a valve 69 is connected to a pump 52 for providing a predetermined fluid pressure. A pipe 53 is leading the fluid through a valve 55 to the fluid inlet pipe 48 having a pressure gauge 54. Before the valve 55 a pipe 56 is connected to the pipe 53 via a valve 57, with the other end of the pipe 56 being connected to the fluid outlet pipe 49. The fluid inlet pipe 48 is connected to a pipe 58, which via a valve 59 leads to a container 60 for containing filtered particles or deposit being removed from the fibre housing during a flushing process. The fluid outlet pipe 49 is further connected to a pipe 61, which via a valve 62 leads to the deposit container 60. The fluid outlet pipe 49 also has a pressure gauge 63, and after the connections to pipes 56 and 61, the fluid outlet pipe 49 is connected to a pipe 64, which via a valve 65 conducts the filtered fluid to a container for filtered fluid 70.

In Fig. 2 is also shown an inlet 66 which via a valve 67 is connected to the pipe 56. Furthermore a valve 68 is inserted in the pipe 56 before the connection to the fluid outlet pipe 49. The inlet 66 may be used for injecting or conducting a liquid, air or a gas into the system to be used for a flushing process. The liquid, air or gas should have a pressure being high enough to flush the system.

When the system of Fig. 2 is operating in a filtering mode, the compression means 45a, 45b is providing a predetermined pressure on the fibres within the fibre housing, the valves 69, 55 and 65 are open, the valves 57, 59, 62, 67 and 68 are closed, and the pump 52 is providing a predetermined fluid inlet pressure. This pressure may for example be up to 20 bar, such as up to 10 bar, such as in the range of 5-10 bar. When the filtration process has been going on for some time, the fibre within the fibre housing 42 may need to be flushed.

If a forward flushing using fluid is wanted, the pump 52 may be turned off, the valves 69, 55 and 65 are closed while maintaining the valves 57, 59, 62, 67 and 68 in the closed position, the compression means 45a, 45b is released, then the valves 62, 69 and 55 are opened and the pump 52 is turned on again. This will conduct unfil-

tered fluid through the uncompressed fibres of the fibre housing 42 and through the pipe 61 to the deposit container 60.

If a backward flushing using fluid is wanted, the pump 52 may be turned off, the valves 69, 55 and 65 are closed while maintaining the valves 57, 59, 62, 67 and 68 in the closed position, the compression means 45a, 45b is released, then the valves 69, 57, 68 and 59 are opened and the pump 52 is turned on again. This will conduct unfiltered fluid through the pipe 56, backwards through the uncompressed fibres of the fibre housing 42, and through the pipe 58 to the deposit container 60.

If a forward flushing using inlet 66 is wanted, the pump 52 may be turned off, the valves 69, 55 and 65 are closed while maintaining the valves 57, 59, 62, 67 and 68 in the closed position, the compression means 45a, 45b is released, then the valves 62, 67, 57 and 55 are opened. This will conduct liquid, air or gas from inlet 66 through the uncompressed fibres of the fibre housing 42 and through the pipe 61 to the deposit container 60.

If a backward flushing using inlet 66 is wanted, the pump 52 may be turned off, the valves 69, 55 and 65 are closed while maintaining the valves 57, 59, 62, 67 and 68 in the closed position, the compression means 45a, 45b is released, then the valves 67, 68 and 59 are opened. This will conduct liquid, air or gas from inlet 66 through the pipe 56, backwards through the uncompressed fibres of the fibre housing 42, and through the pipe 58 to the deposit container 60.

Usually, a backward flushing process is used in order to avoid any further contamination of the system by filtered particles.

It should be understood that it is also within the present invention to provide a filtering system which is automatically operated by a computer, such as a programmable logic controller, PLC. Here, the computer may be programmed to control the compressing and the release of the pressure means by use of for example hydraulic means. Predetermined pressures and time intervals may be programmed into the computer in order to control such a process. The computer may further be programmed to control the fluid pump 52 and the valves 55, 57, 59, 62, 65, 67 and 68 to be active and non-active at predetermined time intervals.

In Table I is listed the results from a filtration process which used the filtering device of Fig. 1. The fluid to be filtered had a fluid inlet pressure about 2.5-3 bar, and the compressing means was compressed around the fibre housing with a pressure about 2 tons. The fibre bundle of the fibre housing comprised hollow polyester fibres with a diameter about 0.05 mm.

The filtered fluid was ash-contaminated water, where ordinary drinking water was mixed together with ashes from wood. This mixture was measured to consist of water and 95 mg/l soluble solid (dry material). When passed through the filter, there was no more measurable amount of soluble solid in the filtered fluid. The low limit of the apparatus for measuring the soluble solid was 3mg/l, so from the results it is concluded that more than 96% of the soluble solid was filtered out of the water.

The reason for testing the filtering device with this kind of fluid was that this kind of pollution has a wide and natural range of particle sizes.

The fluid to be filtered had following mixture of particle sizes:

Particle sizes: All in (um)	Amount in % of dry material or soluble solid before filtering.	Amount in % of dry material or soluble solid after filtering.
0,49 to 0,91	1.66	0
0,91 to 1,95	2,52	0
1,95 to 4,19	4,63	0
4,19 to 9,00	13,3	0
9,00 to 19,31	34,69	0
19,31 to 41.43	35,15	0
41.43 to 88,91	7,81	0
88,91 to 120,76	0,24	0

Table I

The analysis was run by the VKI-institute, certified in DK- by No. DANAK-Reg. No. 26 on a Mastersizer S long bed Ver. 2.18 instrument from Malvern Instruments Ltd.

A second embodiment of a filtering device according to the present invention is illustrated in Fig. 3. The device of Fig. 3 comprises a fibre housing 301 having the form of a tube. Here, the outer part of the fibre housing 301 is made of a watertight material, which is solid in all the housing length and surrounding a bundle of fibres 302. The bundle of fibres 302 comprises a plurality of fibres extending longitudinally in the fibre housing 301. For this embodiment of the invention, the inner part of the fibre housing 301 comprises compression means 303 in the form of a compression membrane, liner or bellow, which is arranged at a location inside the fibre housing 301 and surrounding the fibres 302. The compression means 303 is made of a flexible material and sealingly connected to the inner wall of the housing 301 by mounting and seal rings 304 and mounting bolts 305. A hydraulic inlet/outlet opening 306 is arranged in the housing 303 for providing and/or controlling a hydraulic pressure whereby the compression means 303 may be compressed against the bundle of fibres 302.

In the illustrated embodiment the fibre housing 301 has an inlet end 307 and an outlet end 308, and the fibres 302 have free fibre ends at the outlet end 308. At the inlet end 307 the fibres are secured to a fibre-head 309, and it is preferred that the fibres 302 are glued to the fibre-head 309 by means of epoxy. The bundle of fibres 302 should be substantially equally spaced when arranged in the epoxy of the fibre-head 309 in order to obtain a number of substantially equally sized interspaces defining flow passages. One or more liquid or fluid inlets may be arranged at or around the inlet end 307 of the fibre housing 301, whereby a liquid or a fluid can be conducted into the fibre housing 301. The fibre housing 301 has one or more liquid or fluid outlets at the outlet end 308, whereby the liquid or fluid can be discharged from the fibre housing 301. The fibre-head 309 is fastened to a fibre-head mounting 310, which is secured to the fibre housing 301, and the liquid or fluid may pass from the inlet(s) through the mounting 310, along the fibre-head 309, and then enter into the bundle of fibres 302 along the outer side of the bundle 302. When a liquid is introduced into the bundle of fibres 302, the fibres may be pressed against the fibre housing 301 and the compression means 303, whereby the liquid will have to pass

through interspaces being provided between the fibres before leaving the fibre housing 301 through the liquid outlet(s).

The fibre-head 309 may be secured to the mounting 310 via a head-bolt 311 having a flush-nut 312 resting on a flush-ring 313. A free-space is provided around the head-bolt 311 within the mounting 310, and a flush-space is provided between the mounting 310 and the fibre-head 309. It is preferred that a ring 314 for providing a turbulent liquid flow, such as for example during a flushing process, is arranged at the inner wall of the housing 301.

It is preferred that the flush-ring 313 has a variable thickness or height and that the flush-nut 312 is dimensioned to fit to the variable height of the flush-ring. Thus, if the fibre head 309 is turned or twisted during for example a flushing process, the fibre-head 309 may be moved to and fro in the direction against the mounting 310. The fibre-head 309 may be twisted due to a turbulent liquid flow, which may be provided by the ring 314.

For the illustrated embodiment of Fig. 3, the fibre housing 301and the mounting 310 may be made of stainless steel while the compression means 303 may be made of a flexible material such as softened PVC or PVC-flexible or rubber. The inner diameter of the fibre housing may in a preferred embodiment be about 100 mm, and the diameter of the fibre-head 309 and the bundle of fibres 302 may be around 76 mm. In one embodiment the fibres are hollow fibres of nylon with a length around 400 mm and a fibre diameter of about 6 mm. The total length of the fibre housing 301 may be 500 mm. Solid fibres may also be used, an in one embodiment solid fibres with a diameter of 2.5 mm are used.

It should be understood that a major advantage of a filtering device according to the present invention is the possibility of flushing the fibres when the pressure on the fibres is released. The flushing process may be either a forward flushing or a backward flushing process. A system, which is capable of performing a forward flushing process is illustrated in Fig. 4, which is a block diagram showing a system using the filtering device of Fig. 3.

In the system of Fig. 4 the filtering device 401 has a fibre housing 402 having a hydraulic inlet/outlet opening 403 leading to compressing means inside the housing for compressing the fibre bundle inside the fibre housing 402. A fluid or gas may be introduced at a certain pressure via the opening 403 in order to compress the fibres. The device 401 further has a liquid or fluid inlet end 404 and a liquid or fluid outlet end 405 for connecting to liquid or fluid inlet and outlet pipes 406, 407, respectively.

The system of Fig. 4 further comprises a container for unfiltered liquid or fluid 408, with a pipe 409, which via a liquid valve 410 is connected to the inlet side of a pump 411 for providing a predetermined fluid or liquid pressure. Furthermore, at re-circulation valve 413 is connected at the inlet side of the pump 411. When the liquid valve 410 is open, the re-circulation valve 413 is closed and the pump 411 is on, the liquid or fluid is provided at a certain pressure at the outlet side of the pump 411.

From the outlet side of the pump 411 a pipe 414 is leading the fluid or liquid through a valve 415 to the fluid or liquid inlet pipe 406. Before the valve 415 a pipe 416 is connected to the pipe 414 via a compression valve 417, with the output of the valve 417 being connected to the opening 403. The opening 403 is also connected to an external control pipe 418 via an external control valve 419 and to a pipe 420 via a decompression valve 421. The pipe 420 is connected to an injector 422.

The output of the injector 422 leads to a container 423 for containing filtered particles or deposit being removed from the fibre housing 402 during a flushing process. The liquid or fluid outlet pipe 407 is further connected to the injector 422 via a pipe 424 and a forward flush valve 425. The liquid or fluid outlet pipe 407 is connected to a pipe 426, which via a valve 427 conducts the filtered liquid or fluid to a container 428 for filtered liquid or fluid.

The compression of the fibres may be controlled externally by adjusting the hydraulic pressure via the external control pipe and valve 419. When operating in this mode, the valves 417 and 421 are closed. When decompressing the compressing means, the decompressing may take place via the valve 419 or by opening the decompressing valve 421. However, it is preferred that the valve 419 is closed and that the compression pressure is controlled via the compression valve 417. Here, valves 415, 413, 419 and 421 are closed while valve 410 and 417 are open and untreated

fluid or liquid is pumped by the pump 411 via pipe 416 into the compression means via the opening 403. When a desired pressure has been obtained, valve 417 is closed, and the system may be used for normal operation.

During normal operation, valves 413, 417, 419, 421 and 424 are closed, while valves 410, 415 and 427 are open. The pump 411 is providing a predetermined fluid or liquid inlet pressure. This pressure may for example be up to 20 bar, such as up to 10 bar, such as in the range of 5-10 bar, or such as in the range of 4-6 bar. When the process has been going on for some time, the fibres within the fibre housing 402 may need to be flushed.

If a forward flushing using fluid is wanted, the pump 411 may be turned off, the valves 410, 415 and 427 are closed, and valves 413, 417 and 419 are maintained closed, the decompression valve 421 and the forward flush valve 425 are opened, then the valves 410, 415 are opened and the pump 411 is turned on again. This will conduct unfiltered fluid forwards through the fibres while at the same time decompressing the fibres by having the injector 422 removing the compression fluid or liquid via the decompression valve 421. The flushing and compression liquid or fluid is conducted via the injector 422 to the waste or deposit container 423.

It should be understood that it is also within the present invention to provide a system according to Fig. 4 for filtering a liquid or fluid, which system is automatically operated by a computer, such as a programmable logic controller, PLC. Here, the computer may be programmed to control the pump 411 and the valves to be active and non-active at predetermined time intervals.

While the invention has been particularly shown and described with reference to particular embodiments, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention, and it is intended that such changes come within the scope of the following claims.

CLAIMS

1. A device for filtering a fluid comprising:

a fibre housing having an inlet end with at least one inlet and an outlet end with at least one outlet, said fibre housing surrounding and defining an outer bound for

a plurality of fibres extending longitudinally in the fibre housing between the inlet end and the outlet end, longitudinally extending interspaces being provided between the fibres, said interspaces defining a plurality of flow passages for the fluid,

wherein at least part of said fibre housing is formed of a flexible membrane surrounding the fibres, and

compressing means is provided for creating a pressure on an outer surface of the flexible membrane thereby compressing the fibres in a radial direction at at least one location along the length of the fibres.

2. A device according to claim 1, wherein said fibre housing has the form of a tube-like member.

3. A device according to claim 1 or 2, wherein at least part of said fibre housing has a cross sectional geometric shape which is substantially equal to a shape selected from the group comprising: a circle, an oval, an ellipse, the shape of a drop, and a polygon.

4. A device according to claim 3, wherein said polygon shape is selected from the group comprising: a triangle, a rectangle, a pentagon, a hexagon, a heptagon, and an octagon.

5. A device according to any of the preceding claims, wherein said compressing means is adapted to create said pressure on a part or a portion of said outer surface of the flexible membrane, said part or portion having a dimension or dimensions in the longitudinally direction of the fibres being smaller than the total length of the fibres within said fibre housing.

6. A device according to claim 5, wherein the dimension of said pressure part or portion in the longitudinally direction of the fibres is below 0,5 times the total length of the fibres within said fibre housing, such as below 0,4 times, such as below 0,2 times, or such as below 0,1 times.

7. A device according to any of the preceding claims, wherein said compressing means is adapted to create said pressure on a part or a portion of said outer surface of the flexible membrane, said part or portion at least partly covering an outer circumference of said membrane.

8. A device according to claim 7, wherein said pressure part or portion is partly covering an outer circumference of said membrane.

9. A device according to claim 8, wherein said pressure part or portion is covering below 90% of an outer circumference of said membrane, such as below 80%, such as below 70%, such as below 60%, such as below 50%, such as below 40%, such as below 30%, or such as below 20%.

10. A device according to any of the preceding claims, wherein said pressure is created on the outer surface of the flexible membrane through one or more substantially solid compressing member(s) being in contact with said outer surface.

11. A device according to any of the preceding claims, wherein the location at which the fibres are compressed is a predetermined location.

12. A device according to any of the preceding claims, wherein the means for compressing is adapted to vary the pressure created thereby, so as to thereby vary the total cross-section of the flow passages at said location and so as to vary the minimum size of particles being filtered through the fibres.

13. A device according to any of the preceding claims, wherein the compressing means comprises a clamp.

14. A device according to any of the preceding claims, wherein the compressing means comprises at least two blocks being positioned on opposite sides of the flexible membrane, so as to compress the fibres from two sides.

15. A device according to any of the preceding claims, wherein the compressing means comprises hydraulic means for creating a pressure.

16. A device according to any of the preceding claims, wherein the compressing means is adapted to compress the plurality of fibres in a radial direction with a pressure of between 5-20 bar.

17. A device according to any of the preceding claims, wherein the fibre housing is formed of a flexible membrane in substantially all its length.

18. A device according to any of the preceding claims, wherein the fibre housing is made of a material selected from a group comprising: PE (polyethylene), softened PVC, nylon, Teflon, and EPDM-rubber.

19. A device according to any of the preceding claims, wherein the fibre housing is arranged within a holding member.

20. A device according to claim 19, wherein the holding member is made of a substantially solid material.

21. A device according to claim 20, wherein the holding member is made of stainless steel.

22. A device according to any of the claims 19-21, wherein the holding member has one or more openings for allowing the compressing means to create a pressure on the outer surface of said flexible membrane of the fibre housing.

23. A device according to claim 22, wherein the holding member has two openings for allowing the compressing means to create a pressure on the outer surface of said flexible membrane.

24. A device according to any of the claims 19-23, wherein the holding member is formed as a tube-like member.

25. A device according to any of the claims 19-24, wherein the holding member has an inlet being sealingly connected to the inlet end of the fibre housing, and an outlet end being sealingly connected to the outlet end of the fibre housing.

26. A device according to any of the preceding claims, wherein the distance between the at least one inlet and the at least one outlet is between 10 cm and 200 cm, such as between 30 cm and 150 cm, such as between 40 and 80 cm.

27. A device according to any of the claims 1-25, wherein the distance between the at least one inlet and the at least one outlet is between 10 cm and 60 cm, such as between 20 cm and 40 cm, such as around 30 cm.

28. A device according to any of the preceding claims, further comprising means for maintaining a longitudinal tension in the fibres.

29. A device according to any of the preceding claims, wherein the internal diameter of the fibre housing is between 1 cm and 20 cm, such as between 2 cm and 15 cm, such as between 3 cm and 10 cm, such as between 4 cm and 8 cm, such as around 5 cm.

30. A device according to any of the preceding claims, wherein the fibres are non-porous.

31. A device according to any of the preceding claims, wherein the fibres are solid.

32. A device according to any of claims 1-30, wherein the fibres are hollow and/or porous.

33. A device according to claim 32, wherein the hollow fibres are closed at fibre ends arranged in the same end of the fibre housing as an inlet to the fibre housing.

34. A device according to any of the preceding claims, wherein the fibres comprise polyester fibres or nylon fibres.

35. A device according to any of the preceding claims, wherein the fibres comprise transparent fibres.

36. A device according to any of the preceding claims, wherein the distance between the at least one inlet and said location is between 5 cm and 100 cm, such as between 10 cm and 90 cm, such as between 20 and 80 cm, such as between 30 and 50 cm, such as around 40 cm.

37. A device according to any of preceding claim 1-35, wherein the distance between the at least one inlet and said location is between 5 cm and 80 cm, such as between 10 cm and 60 cm, such as between 15 and 30 cm, such as around 20 cm.

38. A device according to any of the preceding claims, wherein the fibres at the inlet end of the fibre housing are attached to an end part of the fibre housing.

39. A device according to claim 38, wherein the fibres at the inlet end of the fibre housing are glued to the end part by means of epoxy.

40. A device according to any of the preceding claims, wherein the fibres, in their respective ends, are attached to an end part of the fibre housing.

41. A device according to claim 40, wherein the fibres are glued to the end parts by means of epoxy.

42. A device according to any of claims 1-39, wherein the plurality of fibres comprise a bundle of fibres being bent so that a resulting length of the bent bundle of fibres is approximately between 1/3 and 2/3 of the length of the non-bent fibres.

43. A device according to claim 42, wherein the length of the bent bundle of fibres is about half the length of the non-bent bundle of fibres.

44. A device according to claim 42 or 43, wherein the bent end part of the bent bundle of fibres is arranged in the outlet end of the fibre housing.

45. A device according to any of the preceding claims, wherein the compressing means is adapted to compress the fibres at several locations along the length of the fibres.

46. A device according to any of the preceding claims, wherein the compressing means comprise(s) one or more compressing member(s) having non-flexible and/or flexible part(s).

47. A device according to any of the preceding claims, wherein the fibre housing is made of a watertight material.

48. A device according to any of the preceding claims, wherein the fibres have a substantially circular cross-section with a diameter of at most 5 mm, such as at most 2 mm, such as in the range of 0.001-1 mm, such as in the range of 0.01-0.5 mm.

49. A system for filtering a fluid, said system comprising:
a filtering device according to any of the claims 1-48,
means for passing a fluid to be filtered through the flow passages of the compressed fibres, and
means for maintaining the fibres in a compressed condition while passing the fluid through the flow passages.

50. A system according to claim 49, said system further comprising
means for releasing the pressure on the outer surface of the flexible membrane thereby leaving the fibres in an uncompressed condition,
means for passing a liquid and/or a gas through the uncompressed fibres in a direction from the inlet towards the outlet or in an opposite direction, so as to forward flush or backward flush the device.

51. A system according to claim 50, wherein the liquid to be passed through the uncompressed fibres so as to flush the fibres is unfiltered fluid.

52. A system according to claim 50 or 51, wherein the means for compressing the fibres, the means for releasing the pressure, the means for passing fluid through the compressed fibres, and the means for passing a liquid and/or a gas through the uncompressed fibres so as to flush the device are computer controlled.

53. A method for filtering fluids through a device or a system according to any of claims 1-52, the method comprising:

- passing the fluid through said device,
- compressing the fibres in a radial direction at a location along the flexible membrane, so as to reduce the total cross-sectional area of the fibres and thereby the cross-sectional area of the flow-passages, whereby the cross-sectional areas of the flow-passages gradually decrease towards said location, and
- maintaining the pressure on the fibres while passing the fluid through the flow-passages.

54. A method according to claim 53, said method further comprising transmitting ultraviolet light across the fibres, so as to kill bacteria and/or virus in said filtered particles by use of ultraviolet light.

55. A method of flushing a device or a system according to any of claims 1-52, comprising the steps of:

- releasing the pressure on the fibres, and
- passing liquid or a gas through the uncompressed fibres.

56. A method according to claim 55, wherein the liquid or gas passes the uncompressed fibres in a direction from the inlet towards the outlet or in an opposite direction, so as to forward flush or backward flush the device.

57. A method according to claim 56, wherein the liquid to be passed through the uncompressed fibres so as to flush the fibres is unfiltered fluid.

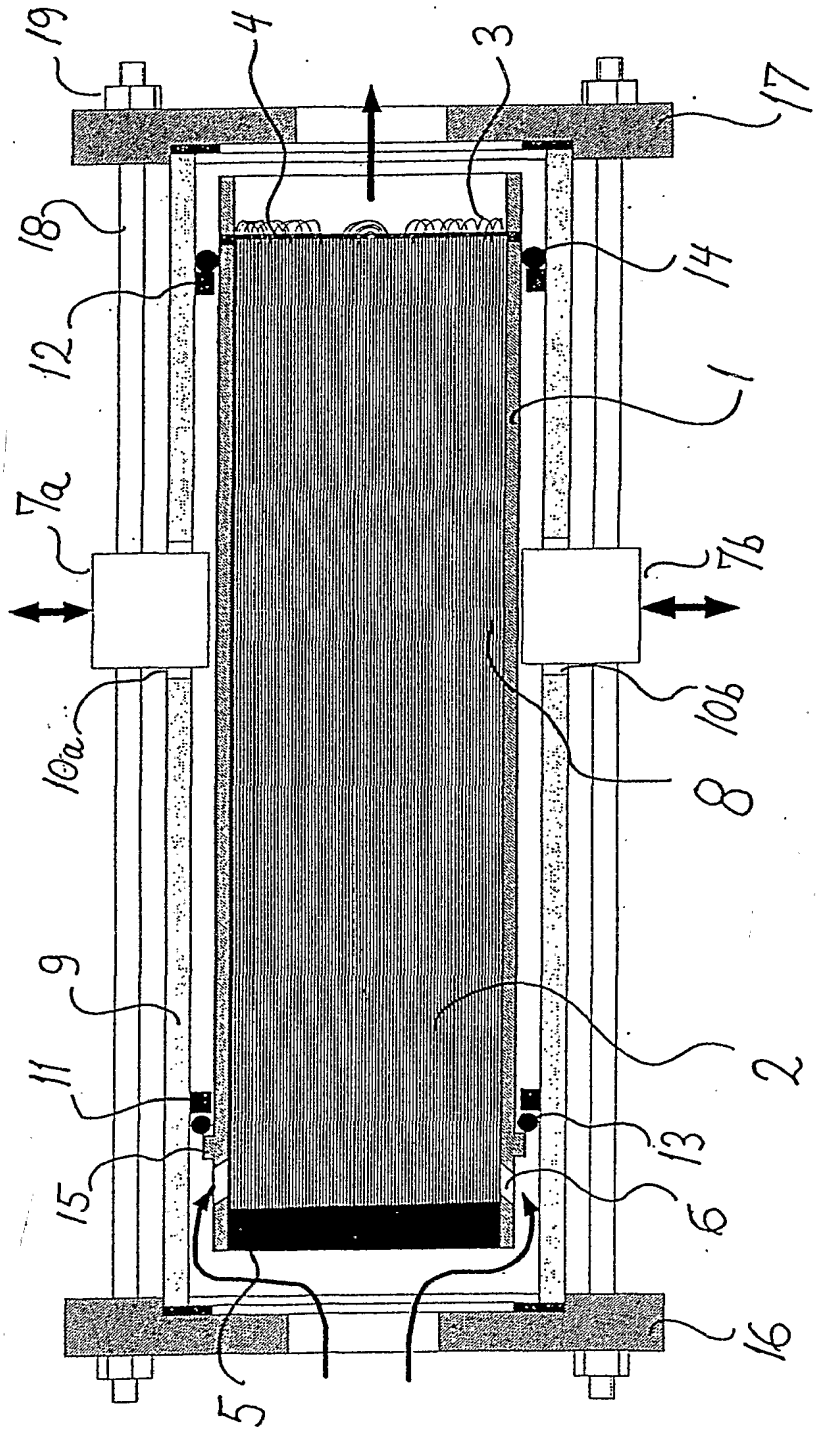

Fig. 1

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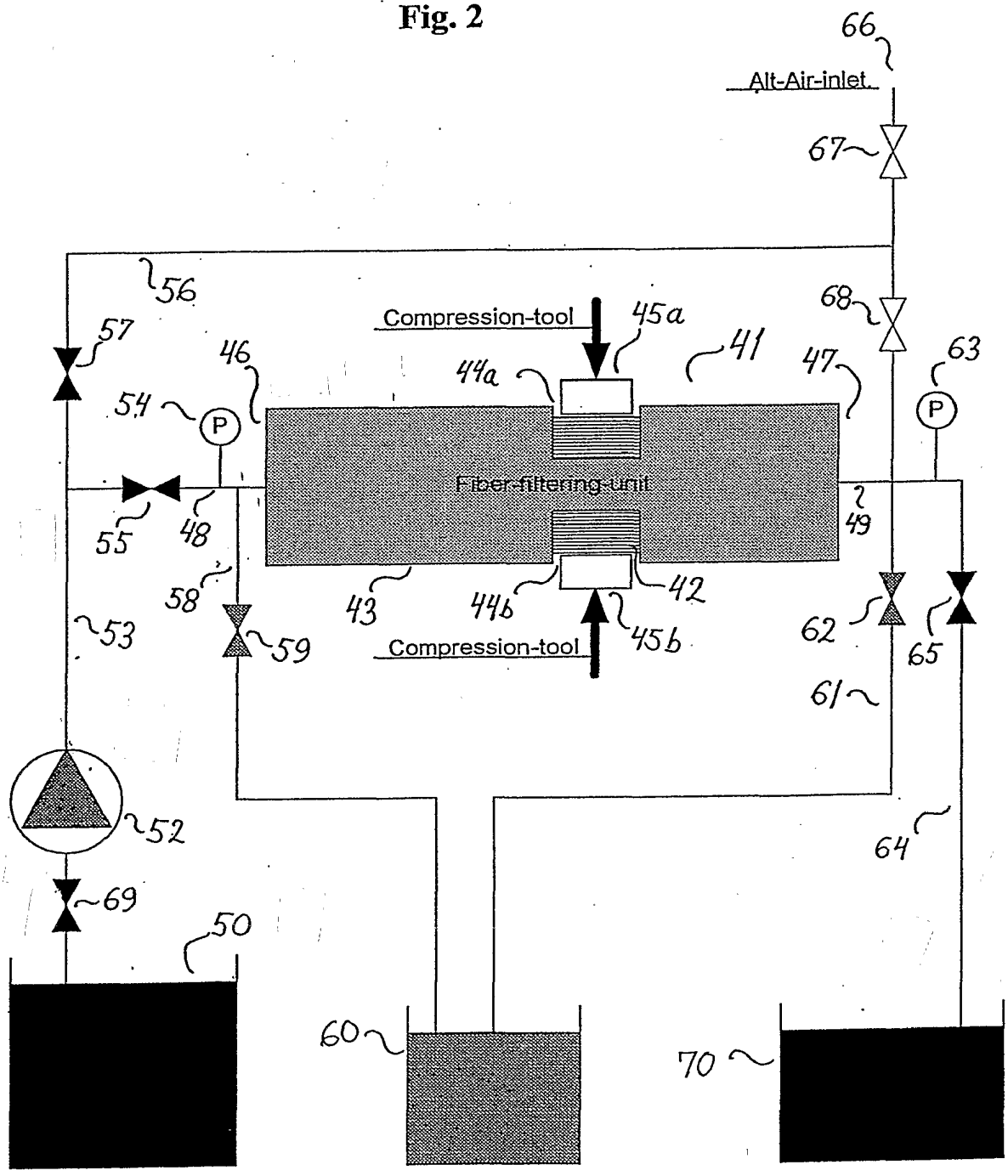
Fig. 2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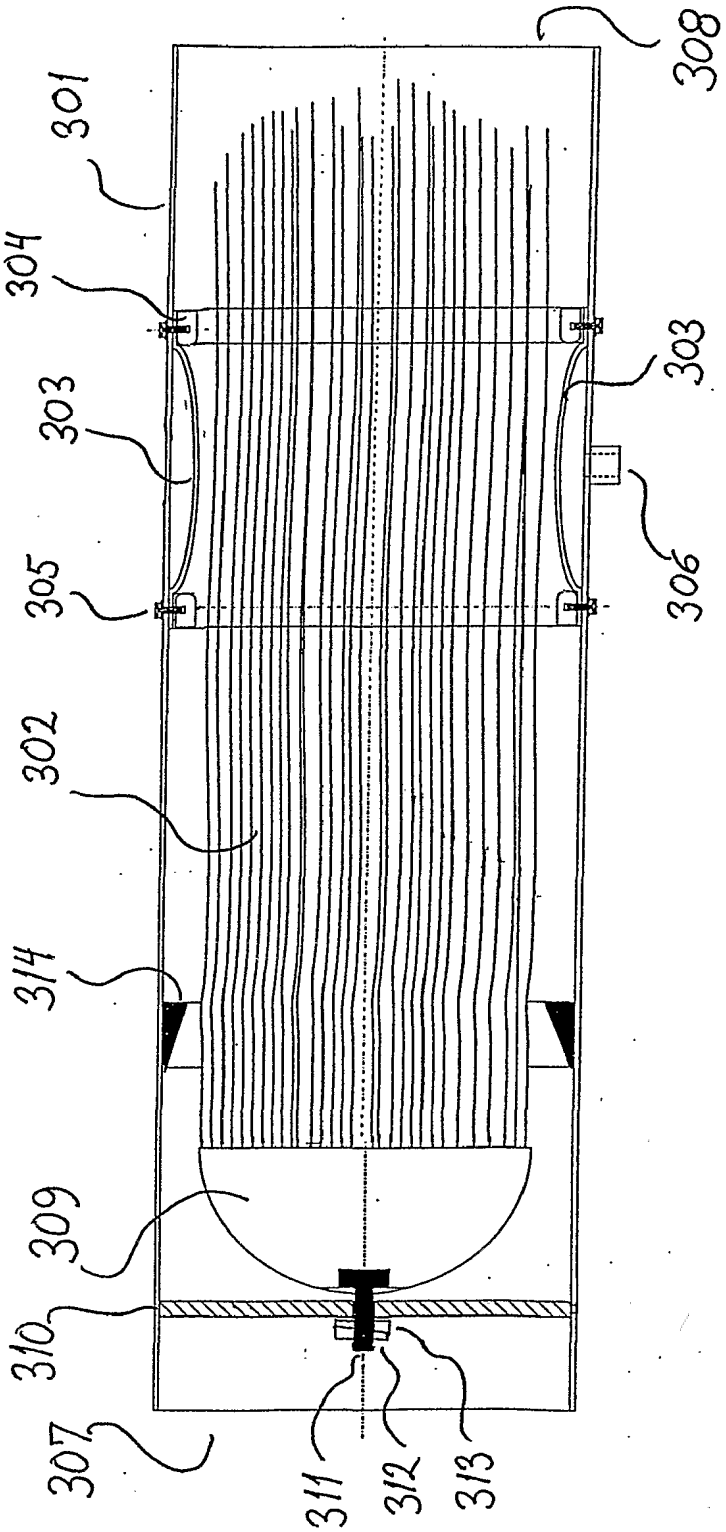
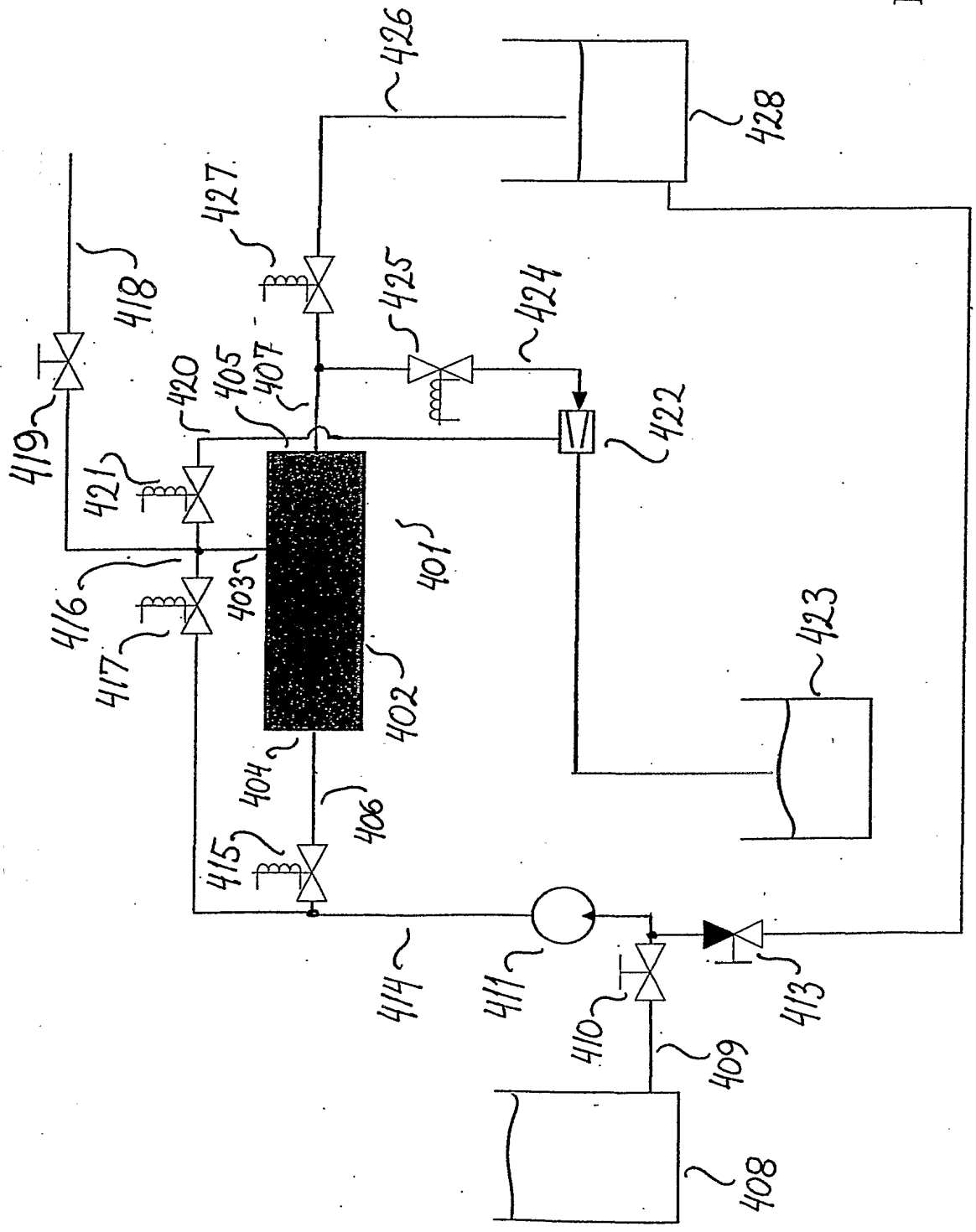


Fig. 3

Fig. 4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INTERNATIONAL SEARCH REPORT

tional Application No
PCT/EP 01/10707

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B01D35/10

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 B01D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 617 120 A (LERNER BOAZ ET AL) 14 October 1986 (1986-10-14) column 1, line 47 -column 1, line 60 column 7, line 21 -column 8, line 14; figure 19	1-3,5, 11,15, 19-24, 49,50
X	US 5 470 470 A (LEYAT JEAN-CLAUDE) 28 November 1995 (1995-11-28) column 3, line 1 -column 4, line 2	53,55,56
A	FR 2 461 514 A (ZHDANOVSKIJ METALL INST) 6 February 1981 (1981-02-06) page 11, line 16 -page 12, line 15; figures 1-5	1-57

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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Date of the actual completion of the international search	Date of mailing of the international search report
28 November 2001	04/12/2001

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

Information on patent family members

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